Lunar Reconnaissance Orbiter: (CRaTER)

Audience
Grades 6-8

Time Recommended
45-60 minutes

AAAS STANDARDS

- 1B/1: Scientific investigations usually involve the collection of relevant evidence, the use of logical reasoning, and the application of imagination in devising hypotheses and explanations to make sense of the collected evidence.
- 3A/M2: Technology is essential to science for such purposes as access to outer space and other remote locations, sample collection and treatment, measurement, data collection and storage, computation, and communication of information.

NSES STANDARDS

Content Standard A (5-8): Abilities necessary to do scientific inquiry:

c. Use appropriate tools to gather, analyze and interpret data.

d. Develop descriptions and explanations using evidence.

e. Think critically and logically to make relationships between evidence and explanations

Content Standard E (5-8): Science and Technology:

b. Technology is essential to science, because it provides instruments and techniques that enable observations of objects and phenomena that are otherwise unobservable due to factors such as quantity, distance, location, size, and speed. Technology also provides tools for investigations, inquiry, and analysis.

MATERIALS

- Pencil and paper
- Make a Cosmic Ray Detector worksheet (one for each student)

CRaTER: The Cosmic Ray Telescope for the Effects of Radiation

Learning Objectives:

- Students will be able to explain CRaTER's purpose and how it works
- Students will "design" a cosmic ray detector to answer their own questions

Preparation:

None.

Background Information:

The Lunar Reconnaissance Orbiter (LRO) is a spacecraft orbiting the Moon. It launched June 19, 2009. It has three main goals:

1. Identify safe landing sites for future human missions to the Moon.
2. Discover potential resources on the Moon.
3. Characterize the radiation environment of the Moon.

The third goal is vital to protecting astronauts on long missions, not just to the Moon, but also to Mars or deep space travel.

LRO carries onboard seven scientific instruments. The primary one for analyzing the Moon's radiation environment is the Cosmic Ray Telescope for the Effects of Radiation, or CRaTER (see **Figure 1**, and others, in the supplemental images/ materials/ resources section; also, see the misconception note in the assessment section). It studies both cosmic rays and how they might affect the human body. You can see in the picture (**Figure 1**) that CRaTER sticks out from the spacecraft. This keeps the spacecraft from blocking cosmic rays from the instrument.

Figure 2 is a photograph of what CRaTER looked like before it was attached to LRO. The right-hand side of the instrument contains the particle detectors. A cut-away version is shown in **Figure 4c**. Inside are six detectors (D1, D2, D3, D4, D5, and D6). The detectors are made from silicon (see **Figure 4**). When a cosmic ray hits a detector, it can create a small current in the silicon. A computer then detects and records the amount of current created.

These detectors allow scientists to figure out how the number of cosmic rays arriving on the Moon changes over time. That number varies, so tracking it for the duration of LRO's mission is important. This tells scientists how the radiation dose changes over time, and how it can affect humans.

Scientists can also use the amount of current in the detectors to calculate how much energy the cosmic ray has and what type of ion it is (e.g. proton, helium nucleus, etc.). You might think that a more energetic particle would create a bigger current, but it is actually much more complicated. Calculating the energy and type of nuclei requires careful computer modeling and testing of the instrument detectors.

CRaTER does more than tell us the number, energy, and type of cosmic rays near the Moon. It also helps scientists learn about how cosmic rays will affect humans on a long mission in space. Notice in **Figure 3** the six detectors are separated into three pairs. Two pieces of black plastic separate the three pairs of detectors. The plastic is a special type designed to mimic human tissue; it is called tissue-equivalent plastic, or TEP (see **Figure 5**). In other words, a cosmic ray will deposit the same amount of radiation in the TEP as it would in human tissue.

Basically, a cosmic ray will pass through the first pair of detectors. That tells us how much energy the particle had. If it has enough energy, it will also pass through the first piece of TEP. Along the way, however, it will lose some energy to the TEP. This means the TEP is receiving a small dose of radiation. The cosmic ray will then pass through the next pair of detectors. Analyzing that signal tells us the cosmic ray now has less energy. By comparing the cosmic ray's energy before and after it passed through the TEP, we can discover how much energy the cosmic ray lost. This energy is the radiation dose the TEP received.

Procedure:

1. Discuss the three goals of the Lunar Reconnaissance Orbiter. Ask students which of LRO's three goals they find the most interesting? Why? Encourage a discussion.

2. Discuss the CRaTER instrument to provide context. See the background information or supplemental resources section for details.

3. Do the lesson activity:

   Objective: Students will "design" a cosmic ray detector to answer their own questions.
   Material: Pencil and paper

   a. Split up students into groups of three or four.
   b. Hand each student the "Make a Cosmic Ray Detector" worksheet.
   c. Have them complete the worksheet.

4. Note: Misconception

   Even though CRaTER is called a telescope, it is not. A real telescope collects electromagnetic radiation to make distant objects appear closer. One example would be the type of telescope you may have used to look at the Moon; it collects and magnifies visible light. However, CRaTER, by contrast, detects particles and not electromagnetic radiation. It does not make distant objects appear closer. Calling it a particle detector rather than a telescope would be more accurate. But scientists enjoy making clever acronyms, so "telescope" it is! (Often they create acronyms that have nothing to do with an instrument's purpose—CRaTER does not actually study lunar craters) worksheet

Name ____

Make a Cosmic Ray Detector

Scenario:

You are a cosmic ray scientist and you need to design a cosmic ray detector for a spacecraft going to Mars. What questions would you like to answer? How will your instrument answer those questions? What do you need to consider when placing it on the spacecraft? Create a diagram of your instrument, and draw what it would look like on the spacecraft.

Answers will vary, but most detectors have some basic needs. They need an internal computer; this computer must connect to the main spacecraft computer, which in turn communicates with scientists on the ground. The instrument's computer needs to keep accurate records of time and the data it collects. Detectors also need electrical power, which comes via wires from the spacecraft itself. A human analogy would be an instrument needs at least one sense (a detector) to interact with its environment, a brain (computer) to interpret the information from that sense, and food (electricity) to keep it working.

worksheet

Assessment:

Discussion Question: Write down three scientific questions that you have about cosmic rays that you think data from CRaTER could answer.

SUPPLEMENTAL IMAGES/ MATERIALS/ RESOURCES:

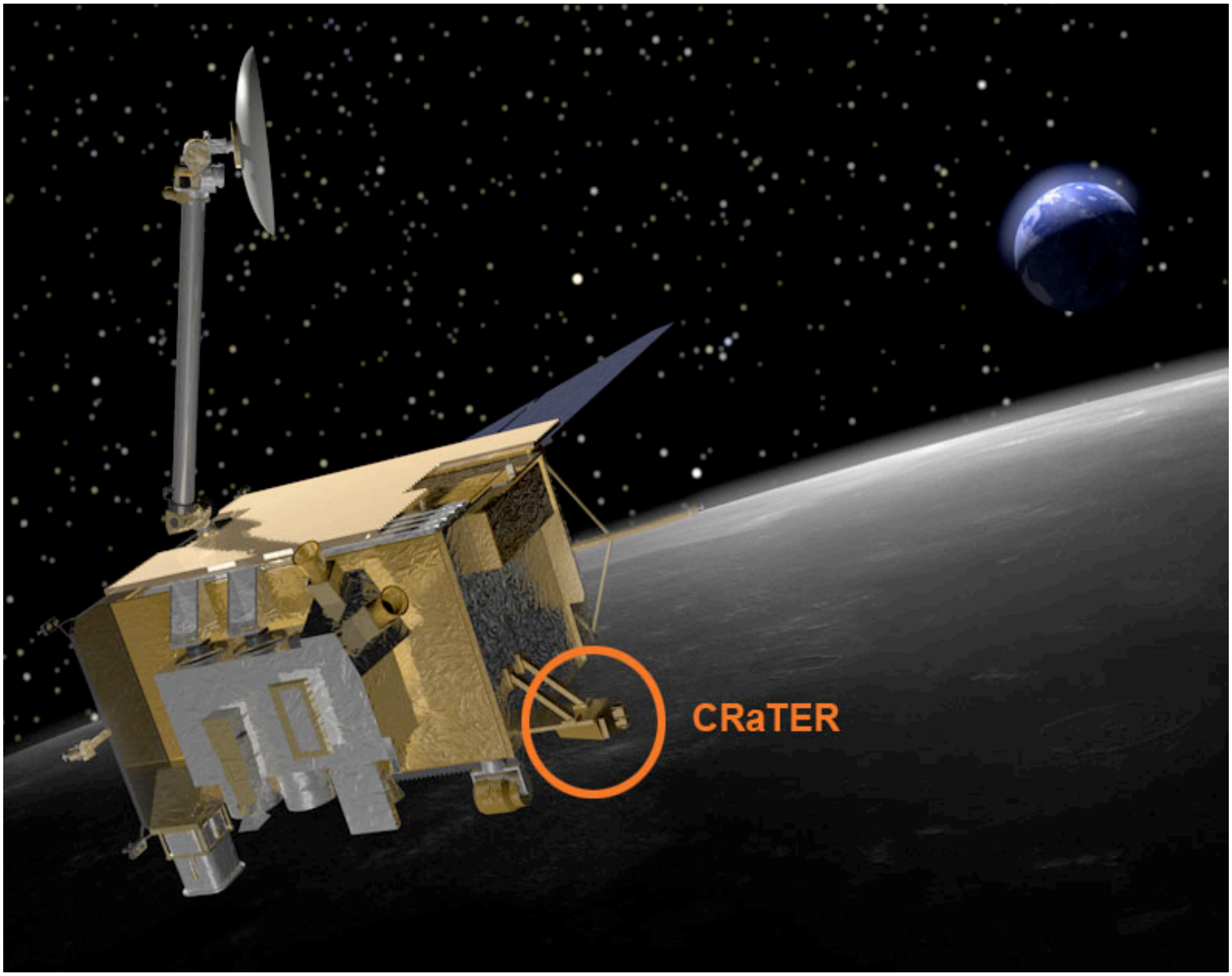

Figure 1. An artist's concept of the Lunar Reconnaissance Orbiter (LRO) above the Moon. The Cosmic Ray Telescope for the Effects of Radiation (CRaTER) is circled.

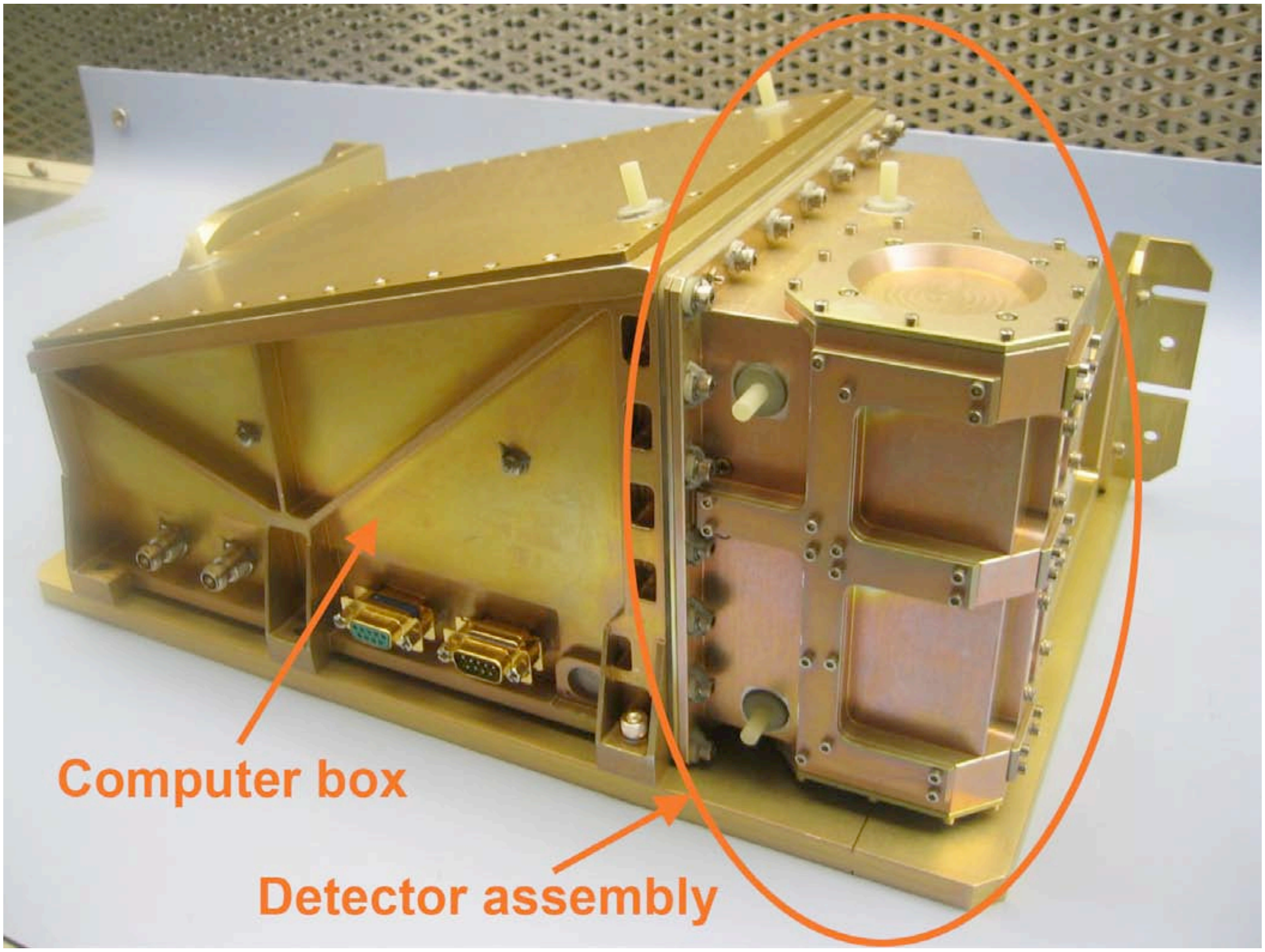

Figure 2. CRaTER before it was attached to LRO. It has two parts: the detector assembly and the computer box.

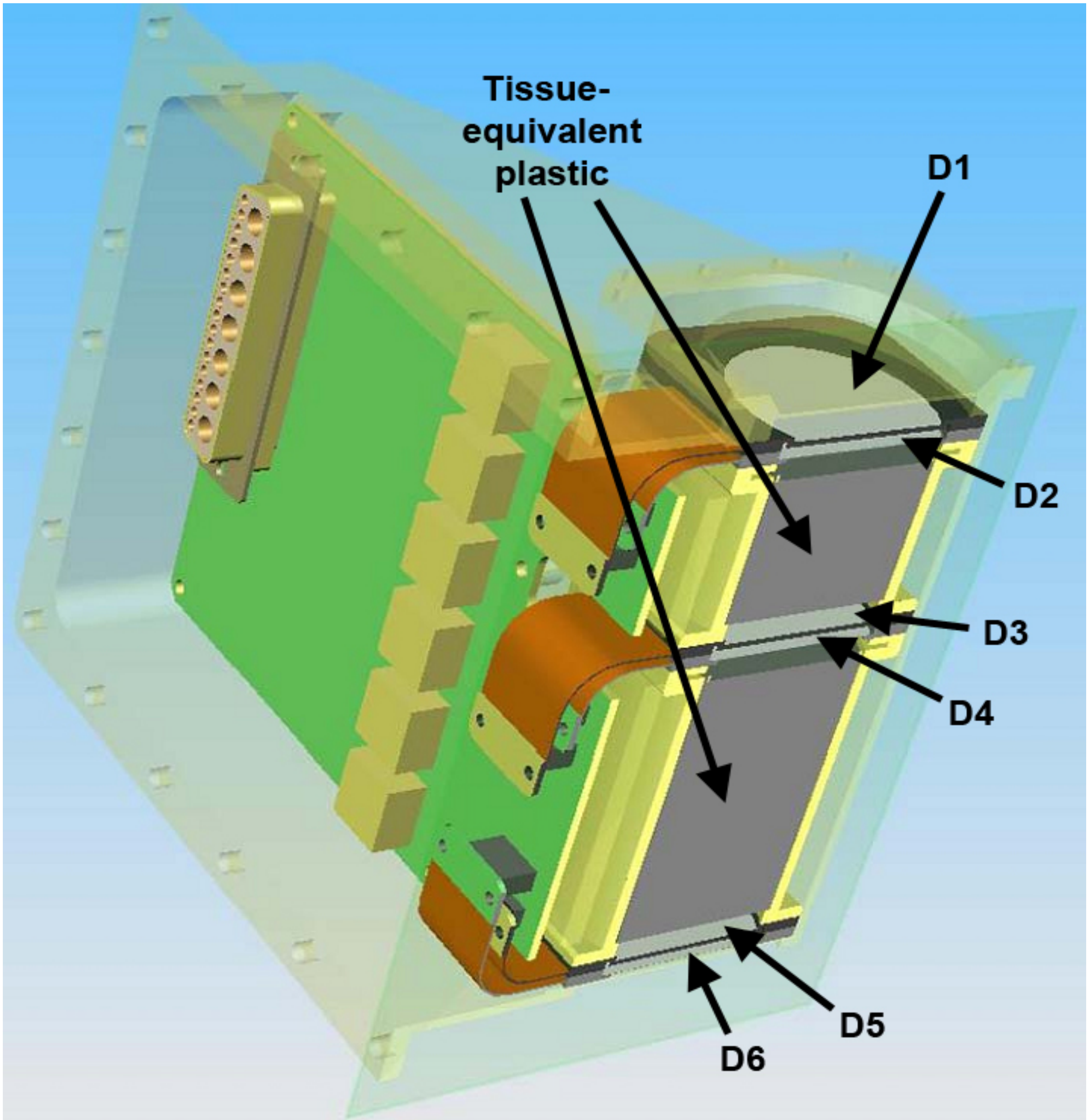

Figure 3. This is a view of CRaTER's detector assembly. It (see Figure 4b) has six "eyes," or detectors (D1, D2, D3, D4, D5, and D6) and two pieces of tissue-equivalent plastic. D6 faces the Moon, while D1 faces deep space. The "brain" of the assembly is the computer on the electronics board. This is plugged into the computer box shown in Figure 4.

Figure 4. This is an up-close view of a particle detector identical to the six in CRaTER (finger is there for scale). The black plastic frame holds the disk. The disk is 140 micro-meters thick and about 4 cm in diameter. The dark gray squares are the silicon, and the lighter edges of the squares are aluminum. The aluminum improves detecting the current created by cosmic rays. The wires run from the detector to a small computer. The detector is very reflective; in it you can see a fuzzy image of pictures hanging on my office wall.

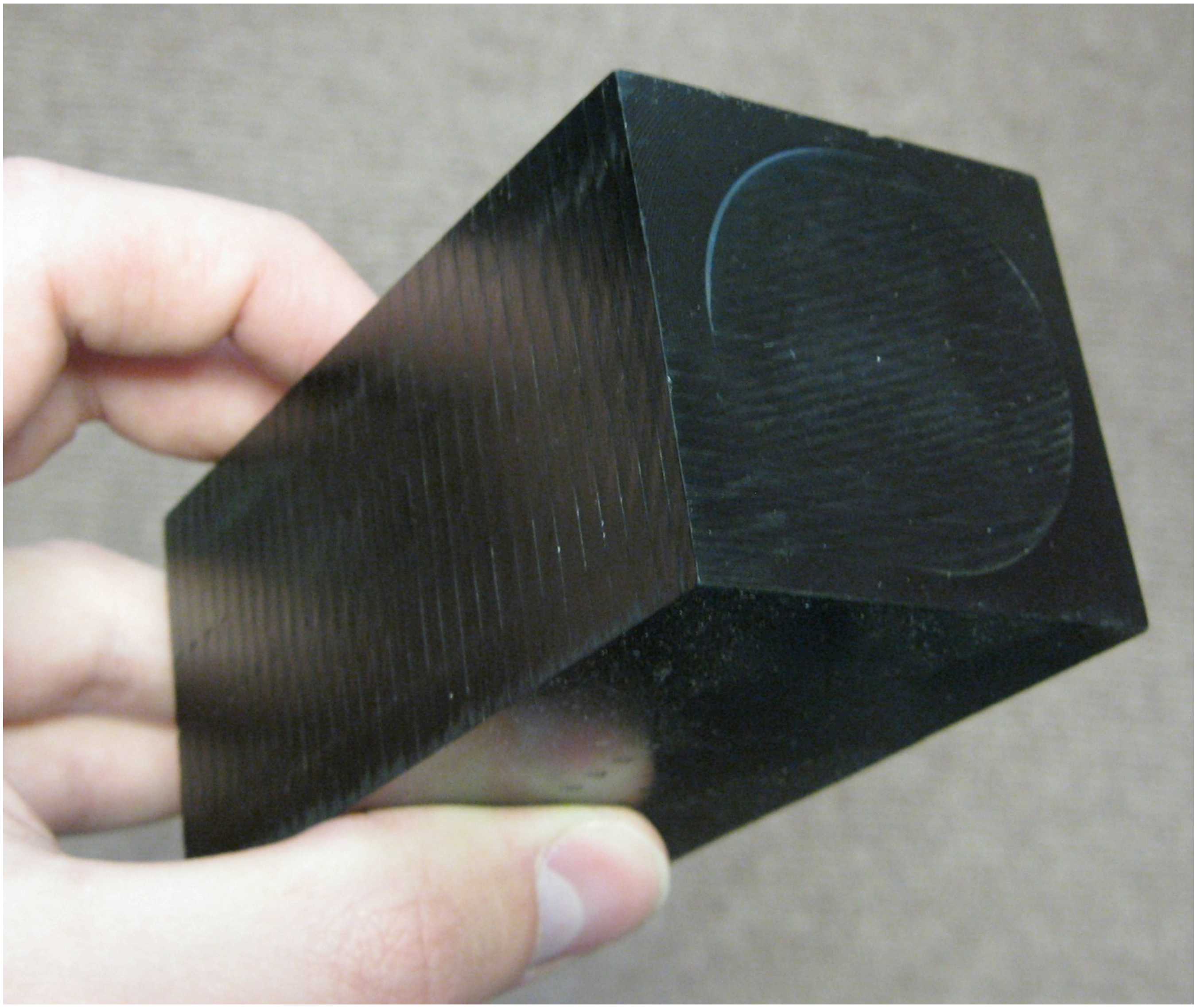

Figure 5. This is tissue-equivalent plastic, TEP: hard and black. Even though it does not look like much, radiation interacts with it almost the same way as with human tissue.

Resources:

Information about CRaTER and LRO

LRO site:
lunar.gsfc.nasa.gov

CRaTER's website:
crater.unh.edu

A video in which the man responsible for CRaTER describes cosmic rays and the instrument:
www.nasa.gov/multimedia/nasatv/on_demand_video.html?param=http://anon.nasa-global.edgesuite.net/anon.nasa-global/ccvideos/GSFC_20090416_LRO_CRaTERvideo.asx

General information about cosmic rays

A Thin Cosmic Rain: Particles from Outer Space (previously published as Cosmic Rays), Cambridge, MA: Harvard, 2000.

Cosmicopia: An Abundance of Cosmic Rays (a NASA Goddard website about cosmic rays):
helios.gsfc.nasa.gov/cosmic.html

Cosmic ray comic book:
www.scostep.ucar.edu/comics/books, then click on the file labeled cosmicrays_e.pdf.

Air shower movies generated from the ARIES (Air shower Extended Simulations):
http://astro.uchicago.edu/cosmus/projects/aires

Space Radiation

Space Radiation Analysis Group at Johnson Space Center:
http://srag-nt.jsc.nasa.gov

Eugene N. Parker, "Shielding Space Travelers," *Scientific American,* March 2006.

M.G. Lord, "Are We Trapped On Earth?" Discover, June 2006.

Cosmic rays and cataracts:
http://science.nasa.gov/science-news/science-at-nasa/2004/22oct_cataracts

A NASA 6-12 educators guide to radiation math, with worksheets for students:
www.nasa.gov/audience/foreducators/topnav/materials/listbytype/Radiation

Glossary:

ALFMED: Apollo Light Flash Moving Emulsion Detector, designed to detect whether cosmic rays create small flashes in astronauts' vision

ALTEA: Anomalous Long Term Effects in Astronauts' Central Nervous System; a device onboard the ISS to determine how cosmic rays affect the human brain

Atom: the smallest particle that still has the chemical qualities of an element; composed of a nucleus and electrons

Cosmic ray: an ion or electron in space that travels at a speed similar to that of light

CRaTER: Cosmic Ray Telescope for the Effects of Radiation; an instrument on the Lunar Reconnaissance Orbiter designed to study particle radiation near the moon

Electroencephalograph: an instrument that records the brain's electrical activity

Electromagnetic radiation: energy emitted in the form of electric and magnetic waves

Electron: a negatively charge subatomic particle; one of three particles to comprise atoms

Electroscope: a scientific tool used to store electric charge

Emulsion: a gel-like substance used to detect electromagnetic or particle radiation

ISS: International Space Station

LRO: Lunar Reconnaissance Orbiter; a spacecraft designed to study the moon's resources and radiation environment

NASA: National Aeronautics and Space Administration

Nucleus: the core of an atom, consisting of at least a proton (in hydrogen), or protons and neutrons

Particle radiation: energy emitted in the form of subatomic particles

Phosphor: a material that, when stimulated, emits electromagnetic radiation

Proton: a positively charged subatomic particle; one of two particles to comprise atomic nuclei

TEP: tissue-equivalent plastic, which has radiation-absorbing properties similar to human tissue

Radioactivity: the condition of a substance to emit ionizing particle or electromagnetic radiation